SOUTHERN FOREST EXPERIMENT STATION

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# INFLUENCE OF SPACING ON GROWTH OF LOBLOLLY PINES PLANTED ON ERODED SITES

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*At age 20, survival, height growth, diameter growth and volume were poorer for trees with initial planting spacings of 4 by 4 feet than for those planted at 6 by 6 or 8 by 8 feet. The strong correlation ($r^2$ = 0.82) found between site index and spacing suggests that for these plantations, height and ultimately site index classification were correlated with stocking density rather than with the actual quality of the site. Therefore, for trees planted at close spacings, the use of the height of dominant trees as the index of site quality may underestimate potential site productivity.*

**Additional keywords:** *Pinus taeda* L., site index, height growth, diameter growth, yield.

A long-standing mensurational question is whether stand density affects height growth, thereby influencing the site index classification of a given forest site. In natural stands, Chisman and Schumacher (1940) observed no correlation between site index and stand density, but in plantations, Gilmore and Gregory (1974) noted reduced height growth among closely spaced loblolly (*Pinus taeda* L.) and shortleaf (*P. echinata* Mill.) pines after 13 growing seasons. The present paper reports the influence of initial planting spacing on survival and growth in plantations of loblolly pines established on eroded sites in northern Mississippi.

## METHODS

The plantations—located on the Tallahatchie Experimental Forest—are part of a reforestation project to restore badly eroded areas once planted to agricultural crops but later abandoned. Surface soils are silt loams of loessial origin, which grade into loamy Coastal Plain sedimentary material on side slopes. In some places, erosion had removed the surface soils to expose heavy loess or Coastal Plain subsoils.

Three 256- by 312-foot blocks were laid out on sheet-eroded ridges and upper slopes. Ridge lines ran east-west. Each block was divided into three contiguous strips running the full width of the block from north to south. One of three planting spacings was randomly assigned to each strip: spacings were 4 by 4, 6 by 6, or 8 by 8 feet; thus, three site aspects (north, ridge, and south) as well as three spacings were tested.

In February 1954, the strips were planted

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with 1-0 loblolly pine seedlings 12 rows wide at the assigned spacing; the area was then surrounded with an isolation planting 50 feet wide. After planting, each strip was subdivided into three square 64-tree plots representing a north, ridge, south aspect. Centers for the north- and south-aspect plots were 80 feet downslope from those of ridge plots.

At the end of the 1955 growing season, all dead seedlings on the plots were replaced by transplants from the isolation strips; the replacements were not included in mensurational computations. Plantation development was monitored at 2-year intervals for the first 10 years of the study and again after 15 and 20 years. For the first 10 years, only survival and height growth were measured; after 15 and 20 years, survival, height of five dominants per plot, and d.b.h. of all trees were measured; form classes were determined for the same five dominants per plot after the twentieth growing season. After heights of representative intermediate or suppressed trees for each diameter class were measured, volumes at age 20 were computed according to Minor's (1950) total height tables.

The influence of spacing and aspect on 20-year survival, diameter growth, height growth, and yield was evaluated by analysis of variance. The relationship of the height of dominant trees to both basal area and stems per acre was determined by regression analysis.

To test whether chance had consigned closely-spaced plantings to poor sites and widely-spaced plantings to the better sites, a soil site index predictive equation, developed from the soil physical property data of the nine plots planted at 8 by 8 feet, was used to calculate soil-based site index values for all plots. The differences between soil site index and tree site index on each plot were then computed and subjected to analysis of variance. The influence of site index, aspect, and spacing on yield was then evaluated by regression analysis. Site indices were based on the heights of 20-year-old dominants at age 50 years (Schumacher and Coile 1960). Results significant at the 0.05 level are reported here.

## RESULTS AND DISCUSSION

### Survival

Stand density significantly affected survival at all three spacings (table 1). After 20 years, survival averaged 18 percent lower on the 4- by 4- than on the 6- by 6-foot plots and 30 percent lower than on the 8- by 8-foot plots. Survival was better on ridge plots than on side slopes.

Table 1.—*Survival, height, and diameter at breast height of 10-, 15-, and 20-year-old loblolly pines planted on three spacings*[1]

| Plantation age | Spacing | Height[2] | D.b.h.[2] | Survival |
|---|---|---|---|---|
| *Years* | *Feet* | *Feet* | *Inches* | *Percent* |
| 10 | 4 by 4 | 23.0 | ... | 89 |
| | 6 by 6 | 26.9 | ... | 92 |
| | 8 by 8 | 28.0 | ... | 93 |
| 15 | 4 by 4 | 38.3 | 4.7 | 76 |
| | 6 by 6 | 43.9 | 6.3 | 86 |
| | 8 by 8 | 44.2 | 7.1 | 90 |
| 20 | 4 by 4 | 46.2 | 5.7 | 56 |
| | 6 by 6 | 53.1 | 7.6 | 74 |
| | 8 by 8 | 53.2 | 8.3 | 86 |

[1] Each value is the average of 9 plots.
[2] Data based on five dominants per plot.

### Height Growth

A comparison of the 4- by 4-foot spacing with the two wider spacings showed that height growth decreased as the number of stems per acre increased (table 1). After 20 years, heights on the 4- by 4-foot spacings were 7 feet shorter than on the two wider spacings. However, there was no significant difference between the heights of trees planted at 6- by 6- and 8- by 8-foot spacings; therefore, planting density apparently has little influence on height growth as planting spacing approaches 8 by 8 feet.

The analysis of variance of soil site index as opposed to tree site index indicated that the dominant and co-dominant trees on the 4 by 4 spacings averaged 15 feet shorter than the height predicted by soil properties. Spacing, not site quality, apparently reduced tree growth on the closely-spaced plots. Soil-site work on well-stocked, even-aged natural stands of loblolly pine has repeatedly shown no correlation between stocking density and height growth. For the plantations evaluated here, however—in which specific stocking densities were forced on the land—height growth apparently decreased with high stand density. Therefore, for trees planted at close spacings, the use of height of dominant trees as the index of site quality may underestimate potential site productivity, since height growth rates may have been reduced by dense stocking.

For all three spacings combined, there was no correlation between height and basal area ($r^2 = 0.04$), although when spacings were analyzed individually, the 8- by 8-foot spacing showed a strong correlation ($r^2 = 0.89$).

Regardless of spacing, heights of dominant trees on ridge plots averaged 5 feet less than those on north or south slopes, a condition reflecting the greater erosion on the ridges. There was no significant difference between the heights of trees on north and south slopes.

**Diameter Growth**

Stocking density significantly affected tree diameter at all three spacings (table 1). After 20 years, diameters of dominants and co-dominants on the 4- by 4-foot plots averaged 1.9 inches smaller than those on the 6 by 6, and 2.6 inches smaller than the 8- by 8-foot plots. Diameters on ridge positions were 0.6 inch smaller than those on side slopes; no difference was noted between spacing treatments on north and south slopes.

**Volume Growth**

Volume growth of trees at the 4- by 4-foot spacing averaged 1.5 cords per acre per year, significantly less than the 2.3 cords per acre per year recorded for the wider spacings. There was no significant difference between the 6- by 6- and 8- by 8-foot plantings (table 2). The

Table 2.—*Yields of 20-year-old loblolly plantations by diameter class*

| Planting spacing (feet) and aspect (by block)[1] | Site index | Form class | Stems per acre | D.b.h. | | | | | | | Volume total |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | 5 | 6 | 7 | 8 | 9 | 10 | 11 | |
| | | | *Number* | *Standard cords per acre* | | | | | | | |
| 4 by 4 | | | | | | | | | | | |
| N | [2]83 | 77 | [3]1233 | [4]10.7 | 19.1 | ... | ... | | | | 29.8 |
| R | 70 | 77 | 1616 | 16.1 | 19.2 | 3.0 | ... | | | | 38.3 |
| S | 74 | 77 | 1701 | 9.4 | 21.2 | 6.1 | 4.0 | | | | 40.7 |
| N | 63 | 72 | 1871 | 5.3 | 4.8 | ... | | | | | 10.1 |
| R | 58 | 67 | 1999 | 7.9 | ... | 2.1 | | | | | 10.0 |
| S | 67 | 77 | 1786 | 11.7 | 9.2 | ... | | | | | 20.9 |
| N | 88 | 82 | 1021 | 13.3 | 15.5 | 11.4 | 5.1 | | | | 45.3 |
| R | 77 | 77 | 1403 | 12.1 | 10.6 | 3.0 | 4.0 | | | | 29.7 |
| S | 77 | 77 | 1191 | 17.5 | 12.7 | 3.1 | 4.0 | | | | 37.3 |
| 6 by 6 | | | | | | | | | | | |
| N | 88 | 77 | 794 | 5.4 | 7.4 | 15.1 | 12.3 | 5.2 | ... | | 45.4 |
| R | 77 | 77 | 945 | 7.8 | 10.4 | 10.8 | 10.8 | 2.2 | ... | | 42.0 |
| S | 83 | 77 | 926 | 6.6 | 11.3 | 14.8 | 14.5 | 2.2 | 2.9 | | 52.3 |
| N | 90 | 77 | 945 | 6.2 | 11.3 | 15.1 | 12.3 | 2.6 | | | 47.5 |
| R | 68 | 77 | 1002 | 7.3 | 15.5 | 8.0 | 1.8 | ... | | | 32.6 |
| S | 83 | 77 | 908 | 4.7 | 11.3 | 20.2 | 7.3 | ... | | | 43.5 |
| N | 88 | 77 | 851 | 3.6 | 12.3 | 24.3 | 8.3 | 2.6 | ... | | 51.1 |
| R | 84 | 77 | 908 | 6.6 | 14.2 | 16.2 | 5.5 | ... | 2.9 | | 45.4 |
| S | 88 | 82 | 813 | 5.9 | 14.4 | 16.8 | 16.1 | 3.0 | 3.8 | | 60.0 |
| 8 by 8 | | | | | | | | | | | |
| N | 88 | 72 | 638 | 1.2 | 5.6 | 7.3 | 21.8 | 10.5 | 3.3 | | 49.7 |
| R | 77 | 72 | 606 | 1.6 | 2.3 | 10.6 | 20.2 | 4.5 | ... | | 39.2 |
| S | 84 | 82 | 606 | .7 | 8.6 | 13.4 | 16.0 | 11.6 | 1.9 | | 52.2 |
| N | 81 | 77 | 564 | 0.9 | 7.4 | 15.2 | 10.1 | 5.1 | 3.2 | | 41.9 |
| R | 67 | 72 | 596 | 2.7 | 6.8 | 8.5 | 4.6 | 1.0 | ... | | 23.6 |
| S | 77 | 72 | 596 | .8 | 7.4 | 12.5 | 13.8 | 2.3 | ... | | 36.9 |
| N | 94 | 77 | 553 | 1.7 | 2.4 | 9.4 | 15.0 | 16.0 | 11.2 | 4.4 | 60.1 |
| R | 92 | 77 | 574 | 1.1 | 4.2 | 11.0 | 18.5 | 17.4 | 1.9 | ... | 54.1 |
| S | 90 | 77 | 511 | .7 | 2.4 | 8.5 | 17.4 | 17.4 | 7.6 | 2.1 | 56.1 |

[1] N=north, R=ridge, S=south.
[2] Based on projected height of dominants at age 50.
[3] Includes stems less than 5 inches d.b.h.
[4] Cubic-foot volumes converted to cords: 1 cord=75 cubic feet.

lower growth rates of the 4 by 4 plots were not due to low form class, which was independent of spacing, but to low average diameters and heights. Fifty percent of the 4 by 4 stems were below merchantable diameter (5 inches d.b.h.) as compared to 14 percent of the 6- by 6- and 2 percent of the 8- by 8-foot plantings. The strong correlation ($r^2 = 0.82$) between site index and spacing reinforces the finding that for these plantings, height and ultimately site index classification are correlated with stocking density rather than with the actual quality of the site.

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